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SELF-EXCITED OSCILLATIONS (FLUCTUATIONS) OF  
ZONAL CURRENTS IN THE ATMOSPHERE

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Previous papers (V. V. Shuleykin, Physics of the Sea, 1941, p 426 and DAN, Vol LII, No 3, 1946) established and showed that weather variations might be due to auto-oscillation (self-excited) processes in the system: ocean-atmosphere-continent.

By modeling auto-oscillation systems, N. L. Byzova (DAN, Vol LXXII, No 4, 1950) discovered extremely interesting self-excited oscillations (fluctuations) of convection currents in a vessel (10 x 30 x 40 centimeters) containing water. The heat source was half of the vessel's bottom, heated from below, while the sink was the other half, cooled by ice, and the free surface of the water.

The self-excited temperature oscillations were continuously related to oscillations of the convection current's velocity and proceeded without damping. The period of oscillations exactly equalled the time required for the current to pass around the entire closed loop. The temperature of the bottom surface remained practically constant or increased monotonically when the heat drawn off by the sinks was less than that supplied by the source. Turbulent effects directly over the heater obviously could not produce oscillations with a period of the order of 4-10 minutes. Consequently, excitation of oscillations was connected only with the periodically recurring passage of water masses over the heater.

From laws of similarity, Byzova proposed that this effect must become weak when the size of the oscillatory system is decreased and, conversely, must become more intense when the size is increased.

This gave rise to the possibility of observing similar phenomena in the atmosphere where certain closed systems of air currents exist.

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In this paper, we will show that self-excited oscillations of current velocities actually do take place in the atmosphere and that these are exactly like those discovered by Byzova in laboratory experiments.

Let us imagine a zonal current in the middle latitudes of the northern hemisphere. The airmasses carried along by this current pass periodically over the "heater," which is the North Atlantic current, and over the "cooler," which in winter is the connected continents of Europe and Asia (North America has little influence upon this "cooler").

By analogy with Byzova's model, we should expect that this would produce self-excited velocity (and temperature) oscillations in the zonal current with a period equal to the time required for the air masses to pass around the world along the given parallel.

Analysis of aerological data obtained by German observatories reveals that oscillations of zonal current, which could be expanded into a fundamental sinusoid and into second and third harmonics, were observed at all those heights which they investigated (up to 5 kilometers). The fourth harmonic was practically absent, but the fifth was extremely sharply-defined.

A diagram constructed by German authors for this fifth harmonic but never explained by them is reproduced in the appended figure. The ellipses are hodographs of the vectors which should be added to the corresponding vectors of the average yearly wind velocity at a given height. The latter are not plotted on the drawing for the sake of clarity. In order to smooth the ellipses, the intervals between points are devoted by numbers, each differing from the next by 6 days. Actually, the period of the fifth harmonic is equal to 73 not 72 days.

The ellipse (1) (the smallest) corresponds to velocity oscillations at the earth's surface; the ellipse (2) corresponds to oscillations at a height of 2 kilometers; and the ellipse (3) corresponds to oscillations at 5 kilometers.

The zero time reading was taken at the time when the maximum velocity deviation from the average occurred in the very lowest layer. As we see, the maximum velocity deviation at 2 kilometers lags approximately 14 days in comparison with the layer next to the earth.

It is quite obvious that the oscillations must be excited in the layer next to the earth which undergoes disturbances from the effect of the underlying surface, i.e.; in a friction layer 0.5 kilometer thick. The amplitude of oscillations increases from bottom to top for the same reason that all disturbances, for example those caused by the transfer of air currents through hills or mountain chains, increase in this direction.

According to Byzova's arrangement, the average-yearly wind velocity  $\bar{u}$  in the friction layer must satisfy the following condition for self-excitation of oscillations:

$$\bar{u} = 2\pi \frac{T}{R} \cos \phi$$

where  $T$  is the period of oscillations,  $R$  is the radius of the earth in the middle latitudes, and  $\phi$  is the latitude. We substitute the numerical values  $T=73$  days,  $R=6366$  kilometers,  $\phi=52.5$  degrees, and find from the formula

$$\bar{u} = 3.89 \text{ meters per second}$$

From the data of the same observatories, we find that the average-yearly current velocity in the friction layer is actually 3.5-4.0 meters per second. This means that the condition necessary for self-excitation of oscillations is satisfied. In general, the period of self-excited oscillations may not be equal to one fifth of the year or any other rounded-off fraction of it.

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But it should be remembered that in geometric addition of the vectors corresponding to wind velocity deviations from the average for many years, the sum can differ from zero only when the self-excited oscillations are characterized by some harmonic (as was true in the case considered).

The appended figure shows that the vector increments provided by the fifth harmonic are about 0.4 meter per second in the lower layer, i.e., 10 percent of the absolute value of the average velocity. But it is quite obvious that these oscillations occur in nature with an inaccurately determined phase which shifts from year to year.

When averaging for many years, geometric addition of vectors unavoidably leads to a great decrease in the total vector, which is used to calculate the average value of the increments. The total may even be quite close to zero if in nature there are no characteristic dates which change little in a year and are marked by especially strong pulses. An example of such characteristic dates are the dates of the "May cold spells."

Thus, it follows that the actual amplitudes of self-excited velocity oscillations are much greater than 10 percent of the average yearly absolute value of the zonal current velocity. This agrees completely with Byzova's experiments, in which velocity oscillations of the order of plus or minus 30 percent of the average value were observed.

It is very striking that the period of 73 days, which stands out sharply in the data of German aerological observations, agrees well with one of the "periods" discovered by Mul'tanovskiy more than 30 years ago in qualitative weather studies. According to Mul'tanovskiy, this "period" was 75 plus or minus 2 days. Now we have established the physical meaning of the "period."

[Appended figure follows]

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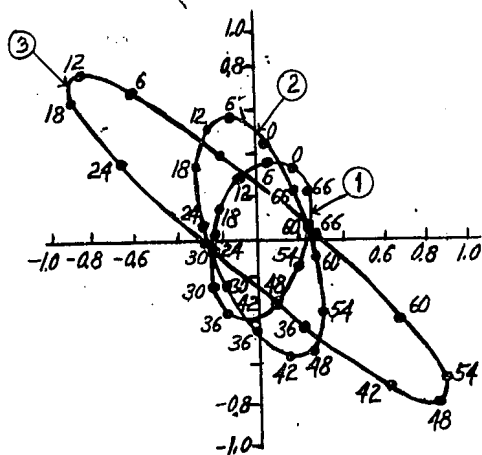
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